RWEQ - Crop Residue Decomposition

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The Revised Wind Erosion Equation (RWEQ) was developed to predict soil loss due to wind using monthly climate data and empirical formulas that consider the effects of soil, crop, and management practices (Fryrear et al., 1994) by the Agricultural Research Service of the United States Department of Agriculture. **RWEQ** uses monthly data but outputs information twice monthly. The residue decomposition component of **RWEQ** was developed to predict residue orientation, mass, and cover based on the decomposition model used in the Wind Erosion Prediction System (**WEPS**) (a daily time step model). Because of the difference in time steps between the two models several of the concepts used in **WEPS** were modified to work in **RWEQ**. The basic hypothesis is that decomposition coefficients account for differences in chemical and physical properties of the residues. Temperature and water functions relate climatic conditions in the field to optimum conditions in the laboratory. Climate functions lead to a decomposition day concept much like a growing degree day where optimum conditions produce one decomposition day in a 24 hour period, while less than ideal conditions produce a fraction of a decomposition day.

In **RWEQ** mass loss is predicted based on an exponential decay equation

$$M_t = M_o * e^{(-k * time)}$$

The equation estimates mass $\mathbf{M_t}$, at time t from the initial mass, $\mathbf{M_o}$, the decomposition rate, **k**, and **time**, since the harvest of the crop. The decomposition coefficients in RWEQ were determined from published articles relating decomposition of whole residue material. **Time** is calculated as decomposition days by using a climatic factor to estimate the relative decomposition conditions during the period. When the climatic factor is optimum during the period then one decomposition day accumulates for each day of the period and decomposition is occurring at the maximum rate determined by **k**. If temperature or water availability are suboptimal few decomposition days and less decomposition are predicted for the period.

Initialization of Decomposition

Crop harvest initializes the residue decomposition routines. The amount of residue at harvest is estimated from yield. Biomass is distributed between standing and flat components based on the harvest height. Economic yield, plant population, crop height and harvest height parameters should be adjusted based on a producers previous management history. These variables are used to estimate the initial residue level, partitioning of residue mass into standing (**M_s**) and flat (**M_f**) pools, and initial stem number (**PSN**).

The total above ground dry matter (**ADM**) and mass remaining (**RESM**) after the yield component is removed are estimated as follows:

ADM = ya + yb*Y	where **ya** is the intercept and **yb** the slope for the relationship between **Y** the economic yield and total biomass (**ADM**) and
$RESM_i$ = ADM - (Y*tof)	where **RESM** $_i$, is the residue mass, **ADM** is the above ground dry matter, **Y** is the economic yield and **tof** is the take off factor which is used for cotton or other crops where a portion of the material removed from the field is non-economic yield.

The coefficients for **ya** and **yb** were determined from published reports in scientific journals or extension articles where biomass at harvest and yield were reported. A number of examples of the type of relationships and data used for the developing the coefficients in **RWEQ** are presented in the appendix.

Partitioning of residue between flat and standing material after harvest is based on the height of the crop before and after harvest.

Mass_flat = RESM * (Crop_ht - harvest_ht) / Crop_ht
Mass_stand = RESM - Mass_flat

In the event that multiple years of a crop sequence is being simulated, each harvest will require initialization. The new M_f and M_s should be added to any value remaining in that variable. If any stems from the previous crop are still standing then the new stem number value should be added to the old value.

Mass and Cover Losses

For each time step climatic data are used to calculate the number of decomposition days (**DD_p**) for the period. Changes in mass, stem number and cover are updated for each period.

Decomposition days (**DD_p**): The **DD_p** in **RWEQ** is calculated as follows:

$$DD_p = 1.25 * TC * RAINDAYS.$$

The **DD_P** for the period is a function of temperature (**TC**) and **RAINDAYS**. Temperature acts to control the rate of decomposition by its control on the rate of chemical and biological reactions particularly the rate of enzyme reactions important in the breakdown of plant material. The **TC** value for each period is calculated with an equation modified from Stroo et al. (1989).

$$TC = \frac{2 \cdot (T-A)^2 \cdot (T_{opt}-A)^2 \cdot (T-A)^4}{(T_{opt}-A)^4}$$

T Period temperature (°C),
T_{opt} Optimum temperature (32 C),
A Coefficient indicating lower limit for microbial activity (OC)

RWEQ calculates **TC** values for the maximum and minimum temperatures for the period and then averages to get a TC value for the period. A is set to 0° to limit microbial activity when temperature is below freezing. The optimum temperature for decomposition is set to 32 C. The minimum value for **TC** is zero.

Water impacts decomposition through its effect on the mobility of microorganism and enzymes. To be effective in the decomposition process microorganisms and their enzymes must move to the residue and brake-down products must diffuse back to the microorganisms to serve as a source of energy and building material. **RWEQ** calculates **RAINDAYS** from the number of days with rain for the month (the value is halved for each semimonthly time step).

RAINDAYS = (number of rain days in the month)

In **RWEQ** we assume that decomposition is restricted by water availability on days without precipitation and there would be no decomposition. On days with rain, water is not limiting and the amount of decomposition is a fraction of one decomposition unit based on the value estimated for **TC**. The **1.25** multiplier used to calculate DDp was included to extend the impact of a single rainfall event beyond one day. This produced a similar cumulative climate index value using monthly data as when using the **WEPS** model which accumulated the daily minimum of a temperature or water coefficient (Steiner and Schomberg, unpublished data from semiarid locations).

Mass loss for standing and flat residues

Mass in the flat and standing pools is calculated each period as a function of $\mathbf{DD_p}$ using the numerical form of the exponential equation. This form is used so that changes in mass or stem number due to mangement operations can be easily incorporated into the calculations.

$$M_{flat} = M_{flaty} * (1 - K_{flat}) * DD_p$$

and

$$M_{stand} = M_{standy} * (1 - K_{stand}) * DD_p$$

where the subscript y indidcates the value from the previous time step.

Conversion of standing residues to flat residues

Initialization of the stem fall routines begins after the number of decomposition days exceeds a threshold value ($\mathbf{DD_o}$). The number of decomposition days since harvest are summed in the variable $\mathbf{DD_{cum}}$.

$$DD_{cum} = DD_{cum} + DD_p$$

Stem fall is estimated similar to that of mass loss

$$SN = SN_y * (1 - K_{sn}) * DD_p$$

where stem number (**SN**) for a period is estimated from the **SN** of the previous period. The equations and coefficients for this equation were determined for small grains by Steiner et al., (1994). As stems fall, mass from the standing pool is added to the flat pool.

$$M_f = M_f + M_s * (PSN - SN) / PSN$$

and mass is removed from the standing pool.

$$M_s = M_s (1 - ((PSN - SN) / PSN)$$

<u>Soil Cover and Stem Silhouette Area</u>

The percent soil cover is calculated using the **flat** residue mass:

$$COV_{flat} = 100 (1 - e^{(mcf * Mf)})$$

Exponential relationships between mass and percent soil cover have traditionally been used. These relationships are species specific and are generally good when developed using randomly distributed, uniform sized pieces of residues. In, field experiments, these relationships are not as clear-cut and are affected by a number of factors. Data collected in a small grain study at Bushland, TX (see appendix) indicated that percent cover was more clearly related to the flat surface residue biomass than to total above ground residue. The relationship is also considerably different between two sample dates (July, 1991, 3 weeks after harvest and August, 1992, 13 months after harvest) particularly when cover is related to total above ground biomass. Using published coefficients, nadir-view cover will generally be overestimated when a large portion of the biomass is in standing stems or oriented in rows rather than randomly distributed. This bias may be partially offset because most precipitation does not fall perpendicular to the earth's surface and standings stems are more effective at intercepting blown precipitation whan would be predicted by the nadir view percent cover.

The stem silhouette area, **SA**, is calculated as:

$$SA = (harvest\ height)^*(stem\ diameter)^*(stem\ number)$$

Revised Wind Erosion Equation (RWEQ)
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Variable list:

<u>Input table:</u>

CH	m	Crop height prior to harvest
HH	m	Harvest height
SDIAM	m	Stem diameter
SN_i	stems/m^2	Stem number at harvest
Y	kg/ha	Marketable yield
dd_o	d	Stem number threshold decomposition days
k_{mf}	d^{-1}	Rate coefficient for flat mass loss
k_{ms}	d^{-1}	Rate coefficient for standing mass loss
k_{sn}	d^{-1}	Rate coefficient for stem number decline
mcf	%/(kg/ha)	Mass: cover conversion factor
ya	(kg/ha)	intercept for yield: drymatter regression
yb	unitless	slope for Yield: drymatter regression
tof	unitless	takeoff factor (if no residue is removed from field, set to 1)

<u>Global - required form other routines</u>:

T_{max}	°C	Average daily maximum temperature by period
T_{min}	°C	Average daily maximum temperature by period
RAINDAYS	d	Average number of precipitation days by period

<u>Internal</u>:

ADM	kg/ha	Aboveground drymatter prior to harvest
M_f	kg/ha	Mass "flat" on surface
M_s	kg/ha	Mass in standing stems
$RESM_i$	kg/ha	Residue mass in field after harvest
SN	stems/m_2	Standing stem number
TC	unitless	Temperature coefficient ($0 \leq TC \leq 1$)
DD_p	d	Decomposition days (DD) for the period
DD_{cum}	d	Cumulative DD since harvest

<u>Global - provided to other routines</u>:

SA	m^2/m^2	Silhouette area per unit soil area
COV_f	%	Percent soil cover

Parameter	Units	Winter	Spring	Oats	Barley	Sunflower	Cotton	Soybean	Corn	Sorghum	Alfalfa	Ryegrass
Y	kg/ha	2000	2000	2000	2000	1000	1000	2000	8000	4000		
CH	m	1	1	1	1	1.5	.7	.7	2.5	1		
HH	m	.25	.25	.25	.25	.5	.5	0	.5	.4	0	
SN	#/m²	500	500	500	500	12	30	20	6	12		
SDIAM	m	.005	.005	.005	.005	.03	.01	.01	.03	.03		
tof	1	1	1	1	1	1	Strip:4.5 Pick: 3.2	1	1	1	1	1
ya	kg/ha	380	380	380	380	0	0		3700	1120		
yb		2.25	2.25	2.25	2.25	3.6	9.25		1.5	1.85		
k_{ml}	d^{-1}	0.013										
k_{ms}	d^{-1}	0.0013										
k_{sn}	d^{-1}	0.169	0.116	0.284	0.176							
dd_o	d_{-1}	17	17.8	17.6	17.3							
mcf	%/(kg/ha)	-0.00065	-0.00065	-0.00119	-0.00065	-0.00017	-0.00025	-0.00065	-0.00043	-0.0003		